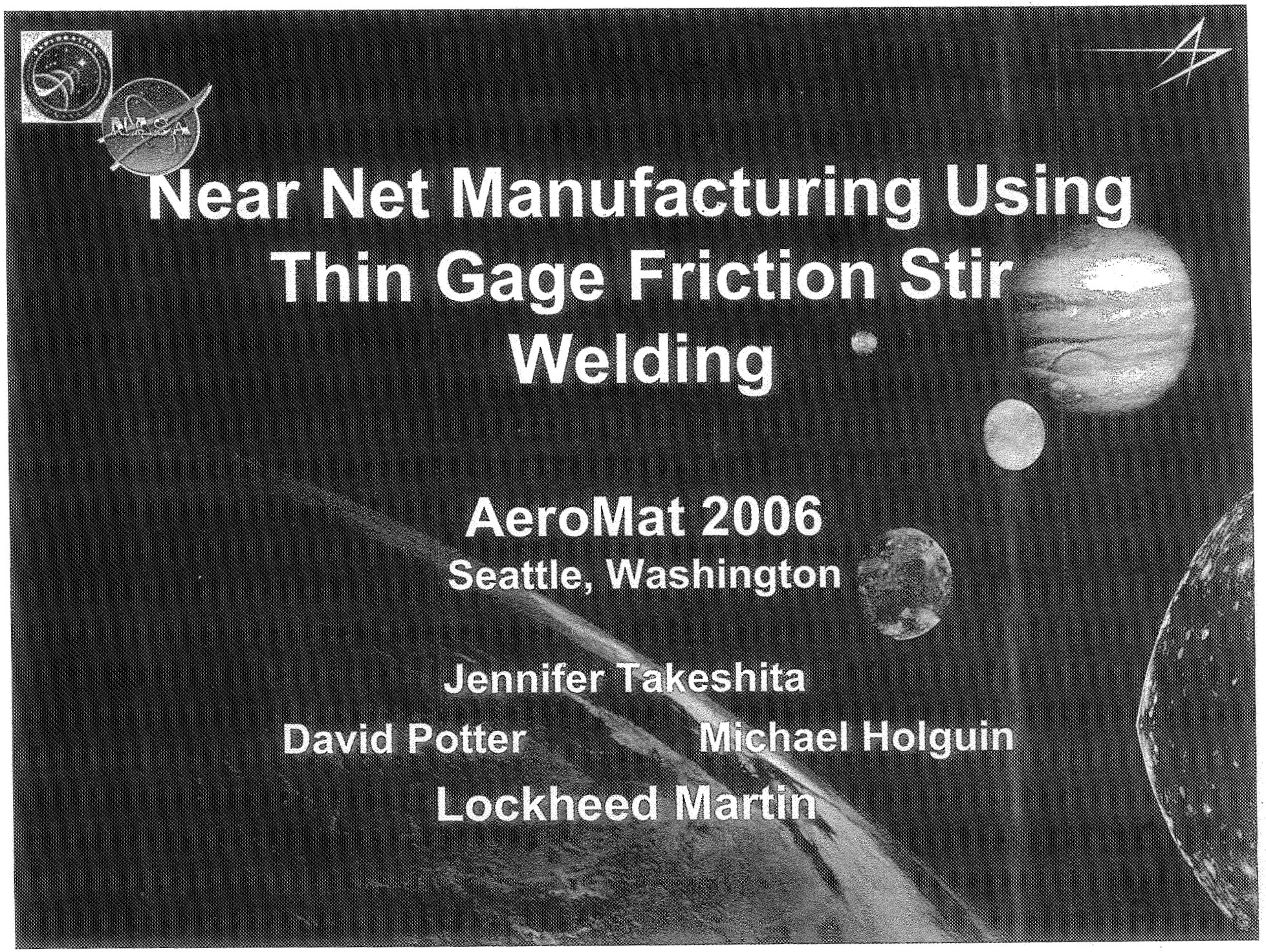


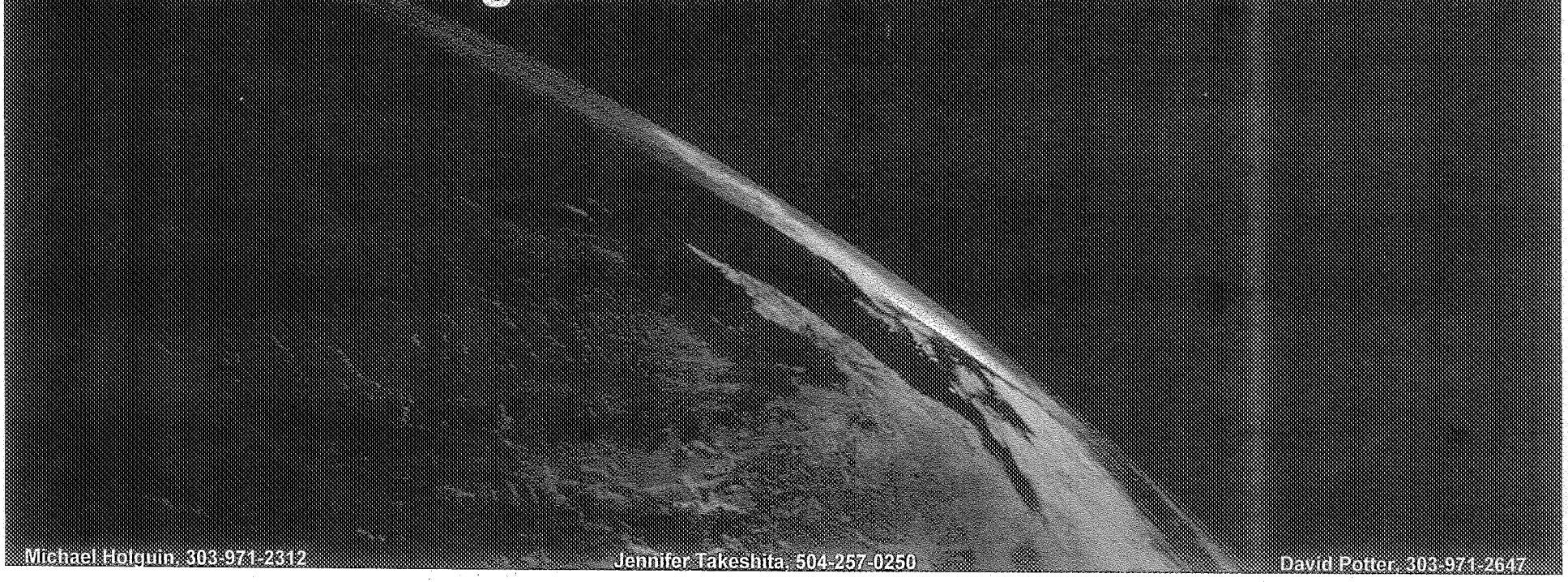
Near Net Manufacturing Using Thin Gage Friction Stir Welding

AeroMat 2006
Seattle, Washington

Jennifer Takeshita
David Potter
Michael Holguin
Lockheed Martin

Agenda

- Background
- Objective
- Approach
- Results
- Acknowledgements



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Background

Work done for NASA's H&RT BAA

- Objective of BAA
  - » Increase the technology level over 4 years
  - » Provide technology that is affordable, multi-purpose
- Focus of this BAA
  - » Friction stir welding on thin gage alloys
  - » Near net manufacturing methods
  - » Mass efficient pressure vessels

Today's Topic

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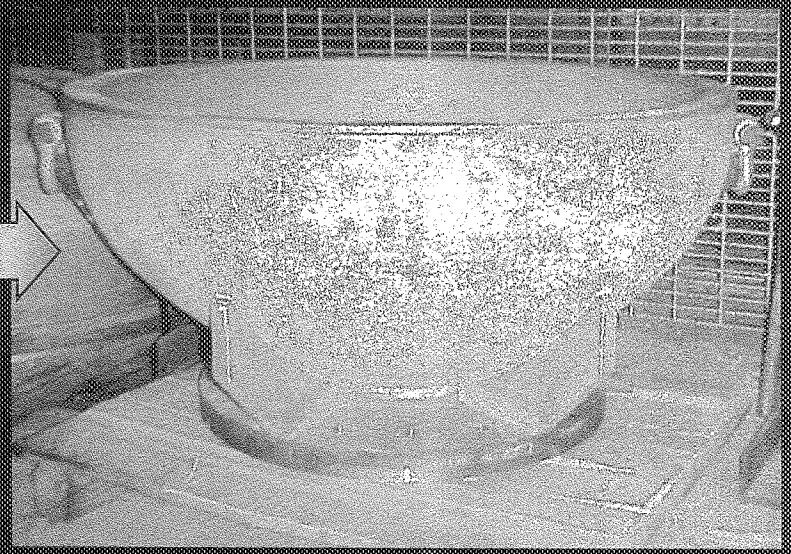
Near-Net Spin Forming

- **Spin form a near-net dome using friction stir welded material**
  - **Technology Development**
    - » Epoxy tool for spin forming
    - » Near net spin forming
  - **Advantages:**
    - » Materials more affordable
    - » Less material to remove if near net
    - » Tooling approach lightweight
    - » Technology is independent of size



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Alloy Selection

- **Select alloys**
  - Criteria
    - » Readily available in gages near 0.125”
    - » Good mechanical properties
    - » Good material properties
      - – i.e. corrosion resistance, density
- **Alloys selected**
  - 2024
  - 2219
  - 7075

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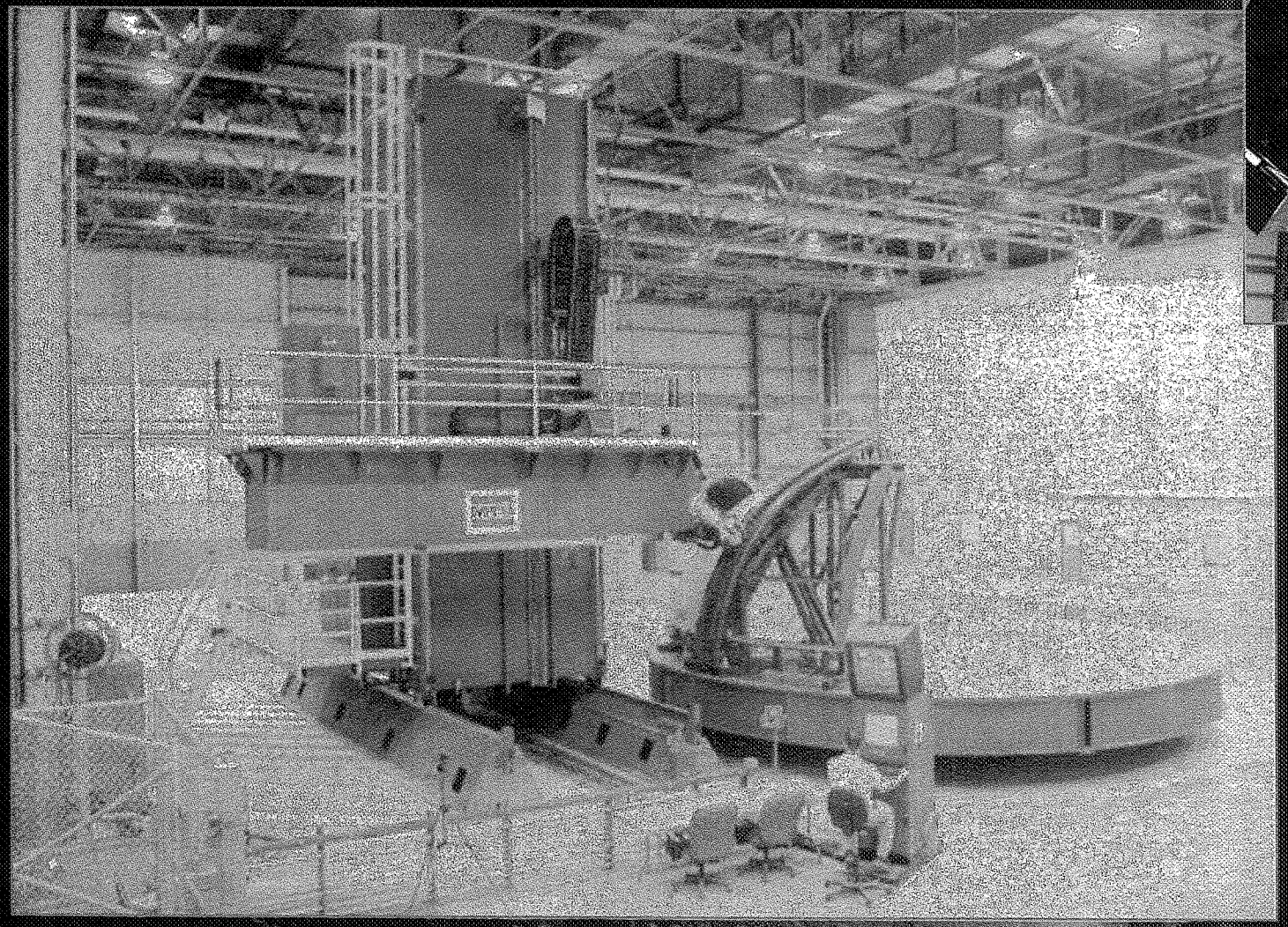
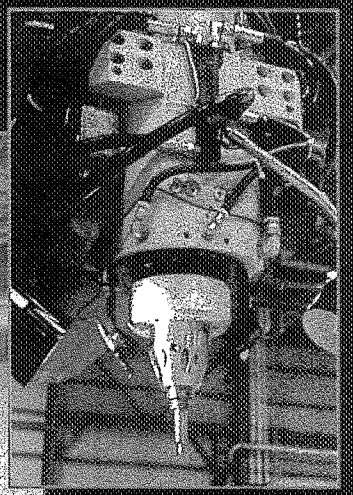
Weld Equipment

- **MTS Universal Weld System**





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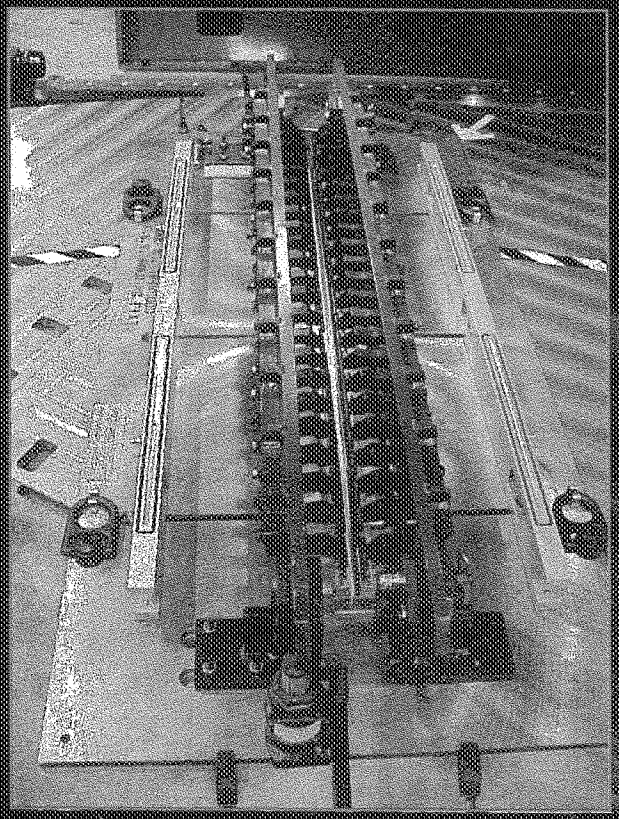
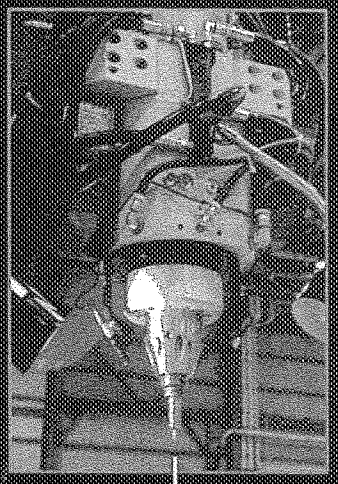
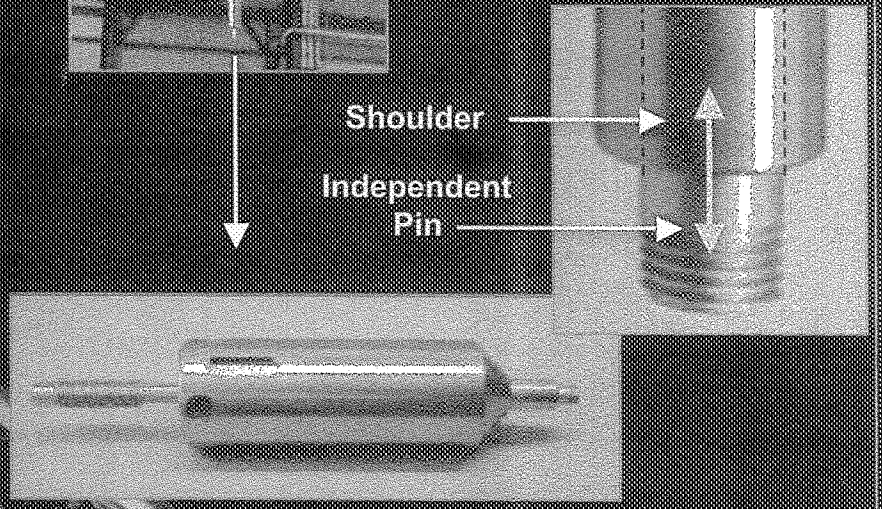
Weld Set-Up

- **Same fixture for all welding**
  - Finger clamping
  - Minimal heat sink







- **Retractable pin tool used for all alloys**

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Weld Development

- **Each alloy was bounded**
- **Bounds were used to run simulated DOE**

18 Welded Panels

Typical Ranges:
- **200 RPM**
- **4 IPM**
- **400 lbf**

2024		Ultimate Tensile Strength	Yield Strength	% Elongation (1")
Parent Metal		64 ksi	47 ksi	12
Weld	Ave	65.5 ksi	47.5 ksi	13.8 ksi
	St Dev	1.0	0.8	1.2
2219		Ultimate Tensile Strength	Yield Strength	% Elongation (1")
Parent Metal		63 ksi	51 ksi	5
Weld	Ave	48.7 ksi	28.5 ksi	5.3
	St Dev	1.95	1.31	0.58
7075		Ultimate Tensile Strength	Yield Strength	% Elongation (1")
Parent Metal		78 ksi	70 ksi	8
Weld	Ave	75.1 ksi	52.9 ksi	7.9
	St Dev	0.76	1.32	0.68

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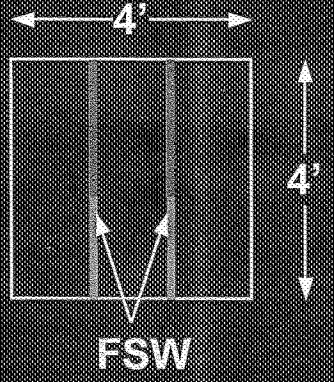
Fabrication of Dome Blanks

- **Deliverable:**
  - Three (3) dome blanks
    - » One per alloy (7075, 2219, 2024)
    - » Final dimensions: 4’ x 4’



- **Process**

Weld Use schedule proven on confidence panels	NDE	Trim to size	Anneal	Ship
7075	Pass	✓	✓	
2219	Pass	✓	✓	
2024	Pass	✓	✓	

Panels remediated after Hurricane Katrina

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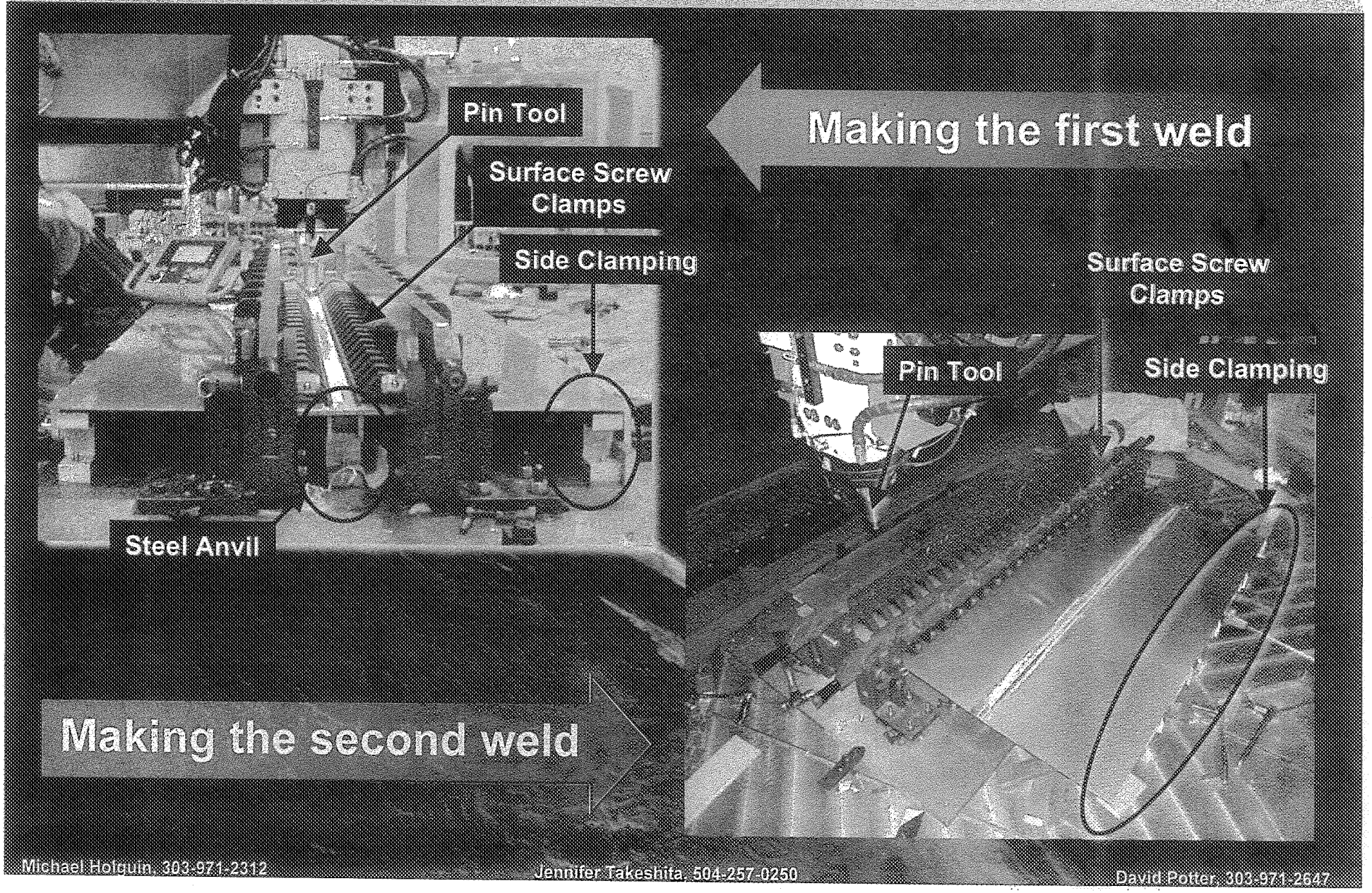
Fabrication of Dome Blanks



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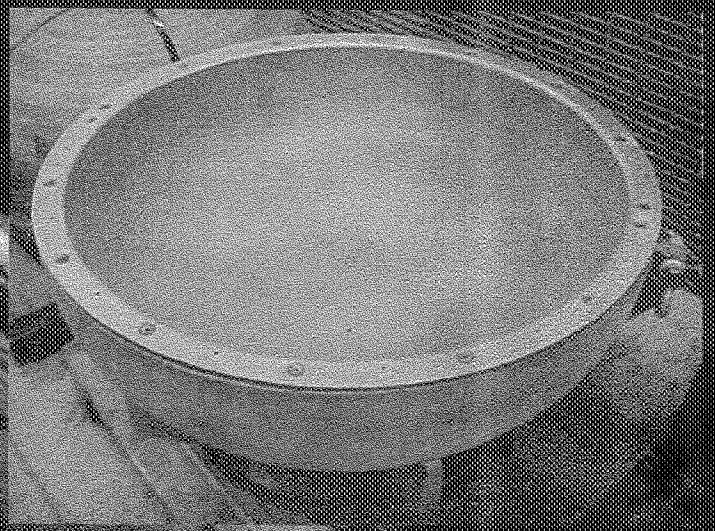
Spin Forming the Dome Blanks

- **Used female mandrel rather than male**
  - » Potential to reduce cost of tooling at large scale
    - – At large-scale, multiple breakdown tools required
  - » Potential to improve control for tolerances and contour
    - – Further enhancing near-net forming capability
- **– Used an epoxy tool with metal ring**
  - » Scale up would cause tool to be too heavy if all metal



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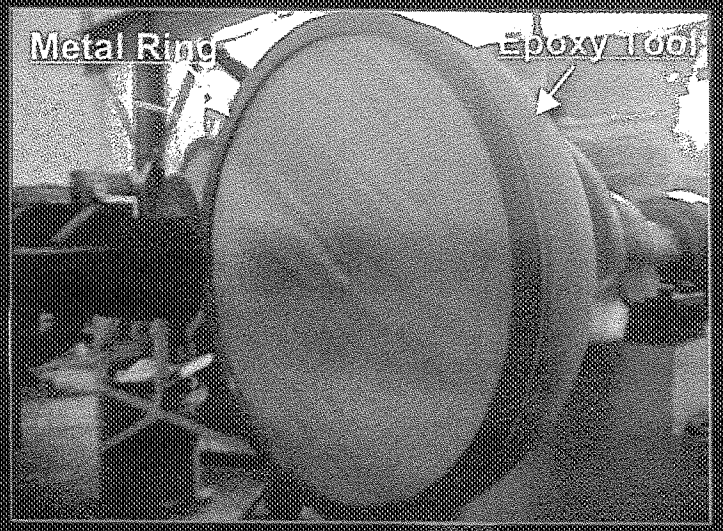
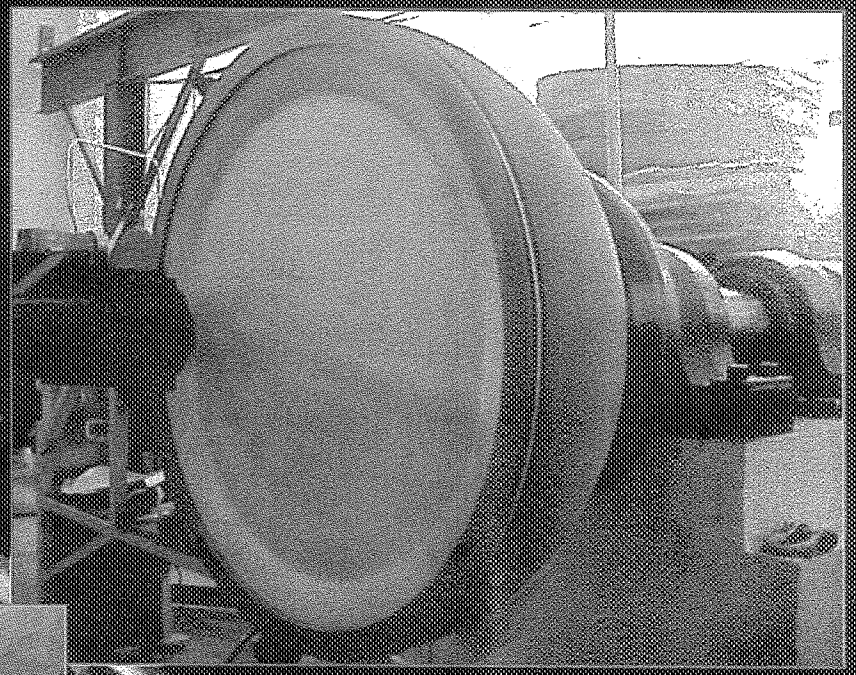
FSW Dome Spinning Process

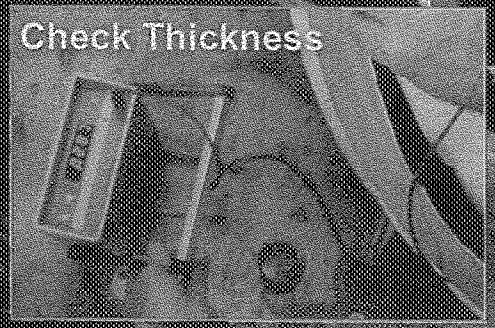
1. Install the dome blank



2. Spin form the blank



3. Check thickness



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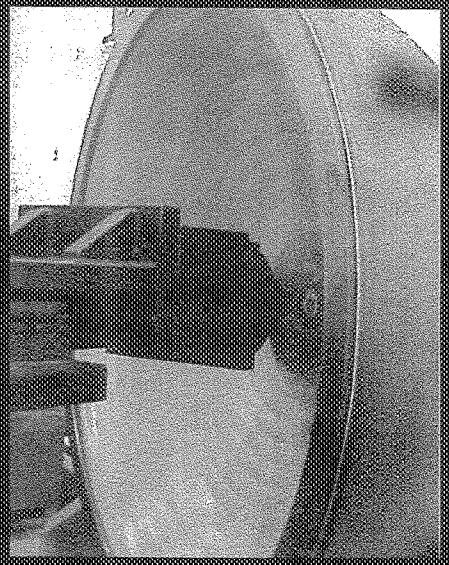
2024 Dome Results

- Material was formed ~ 10-11" inboard prior to cracking
  - Noticeable stress risers on the surface where the crack started
    - » Appears due to hand sanding with 180 grit
  - Material thinned down to ~0.070" near crack initiation
  - Cracking appears to be a brittle failure from being cold worked



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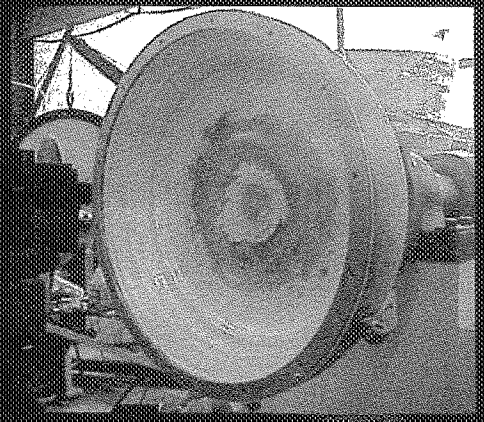
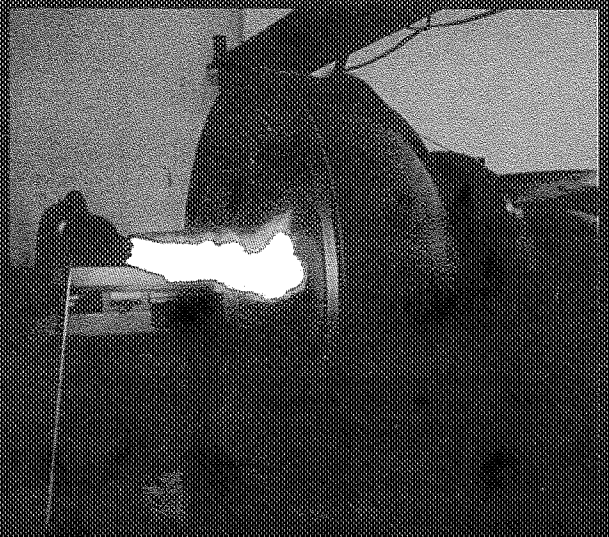
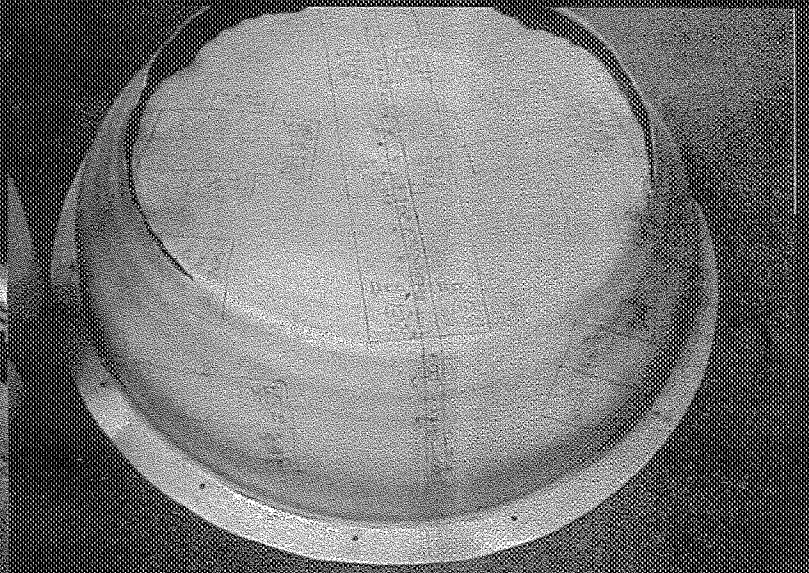
2219 Dome Results

- Heat applied
  - Monitored via IR gun





- Material formed ~10-11" inboard prior to cracking
  - Forming operation was manually controlled
  - Material thinned to ~0.029" near crack initiation
  - Rest of material was ~0.070" thick



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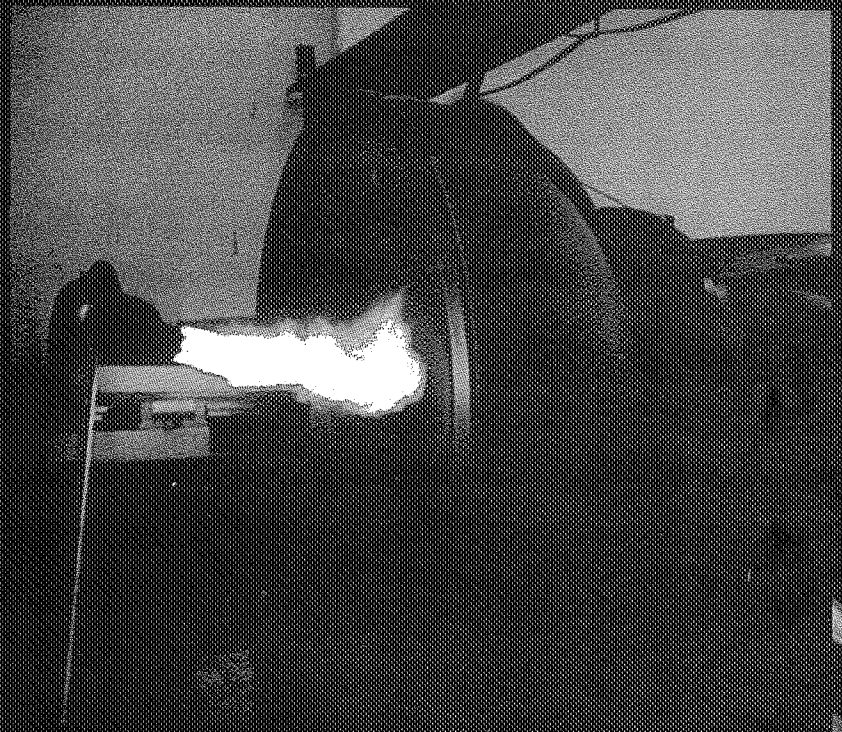
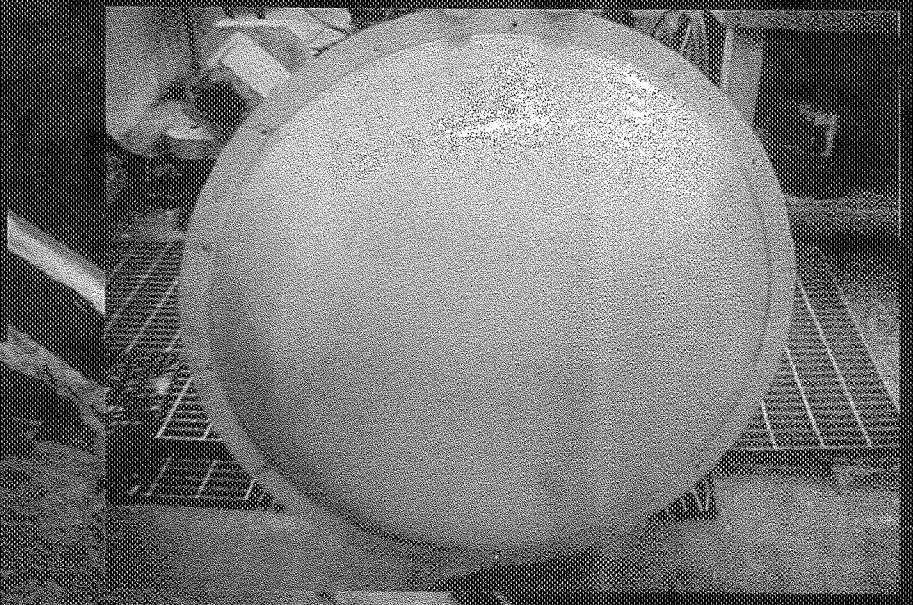
FSW 7075 Blank Spinning

- **Heat applied**
  - Monitored via IR gun



- **7075 Dome Blank:**
  - Material was formed ~10-11" inboard
  - Small tear formed in FSW joint



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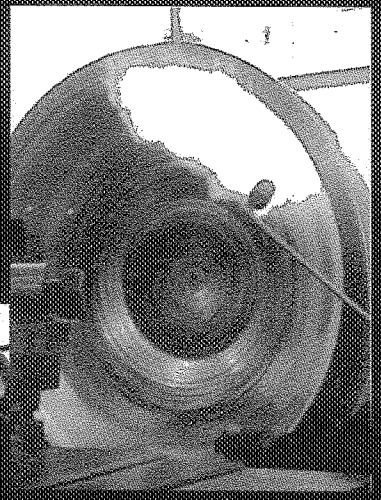
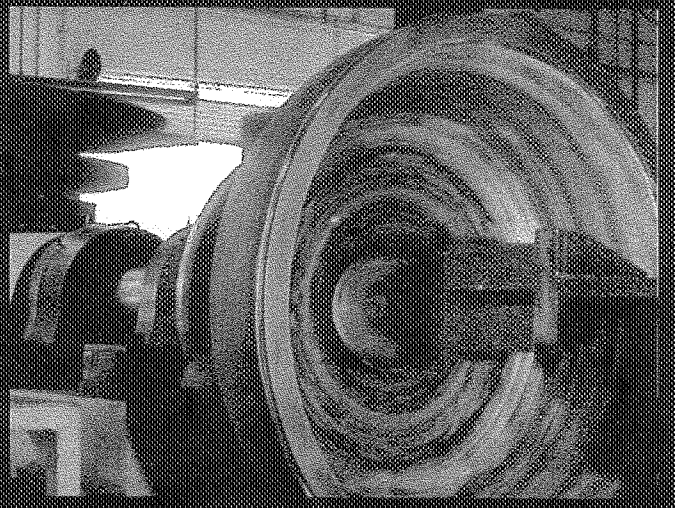
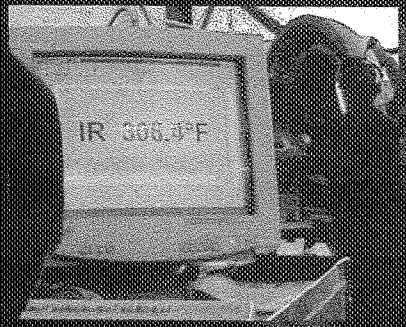
Approach – Round Two (Female)

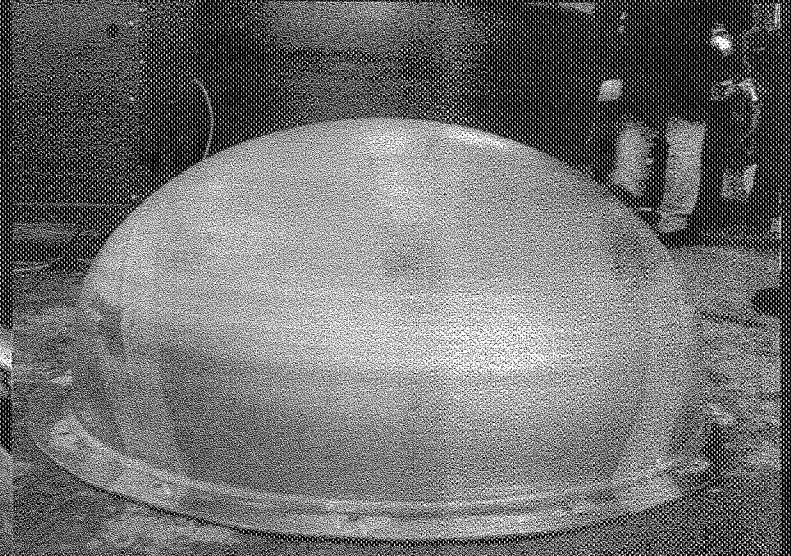
Used 2024 only

Heat applied









Fully formed dome almost accomplished

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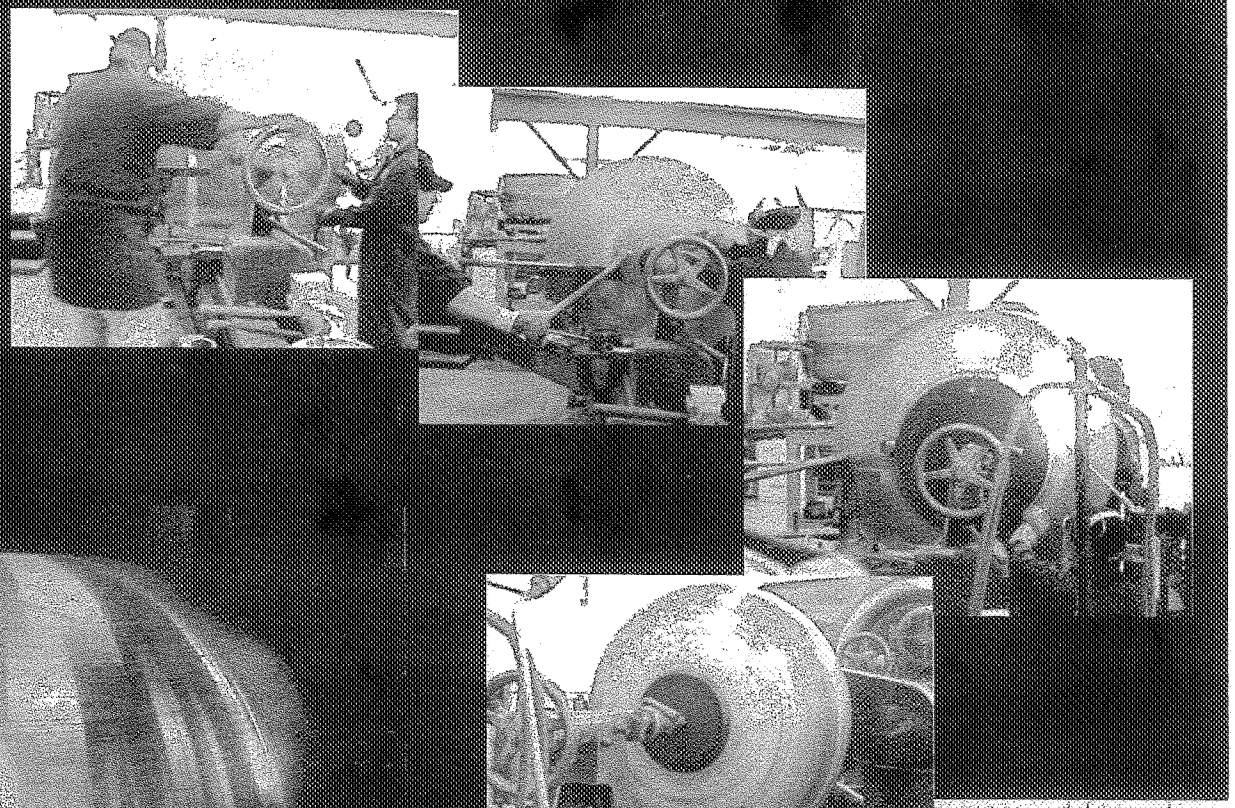
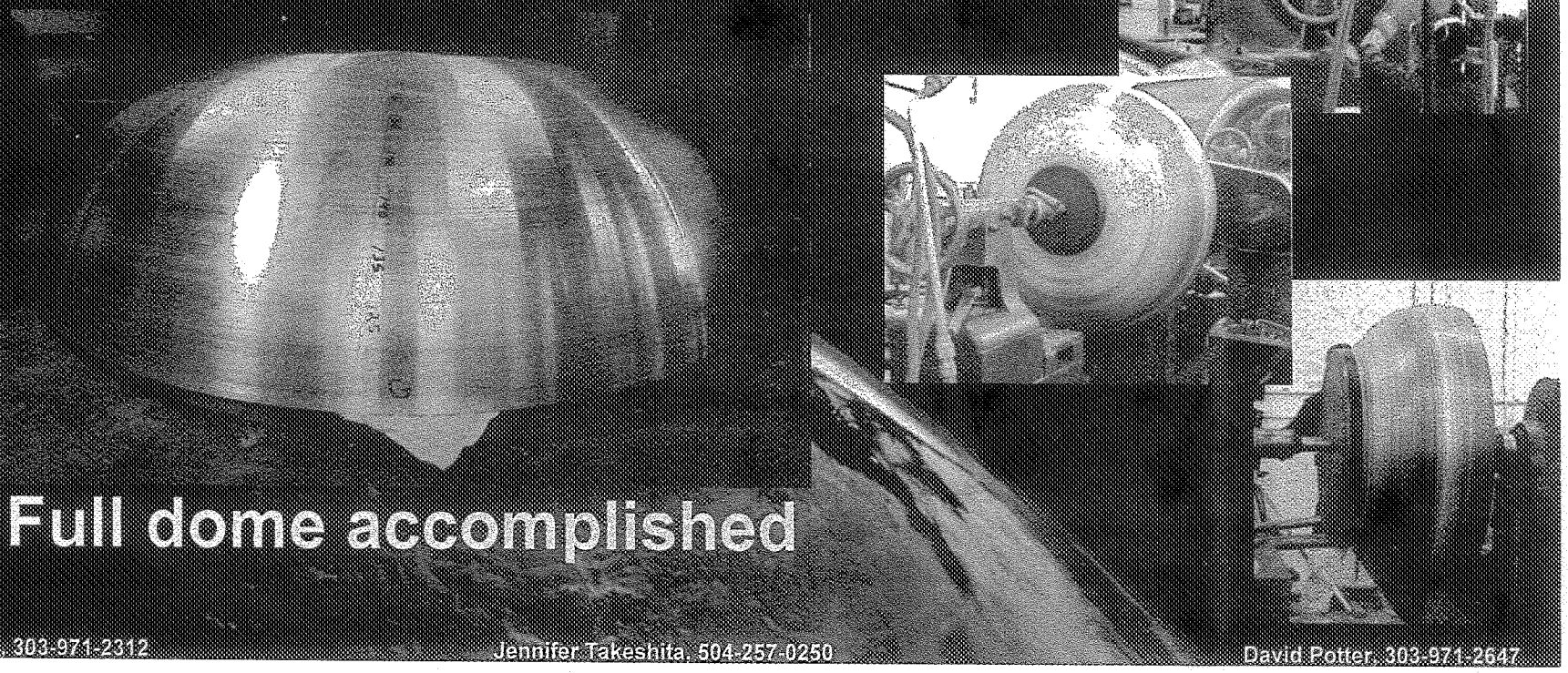
Approach – Round Two (Male)

- Used 2024
- Heat Applied





Full dome accomplished

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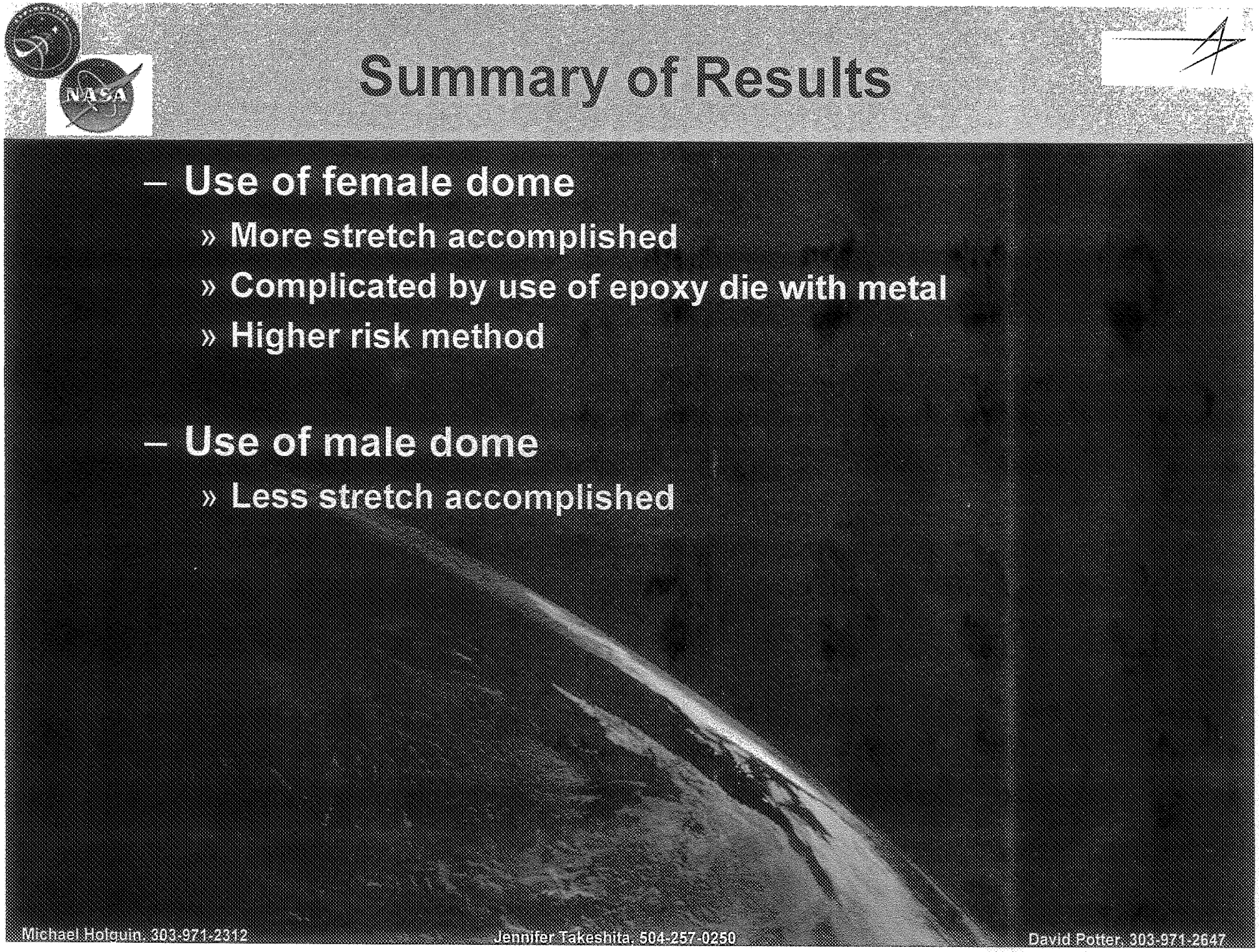
Summary of Results

- Use of female dome
  - » More stretch accomplished
  - » Complicated by use of epoxy die with metal
  - » Higher risk method
- Use of male dome
  - » Less stretch accomplished



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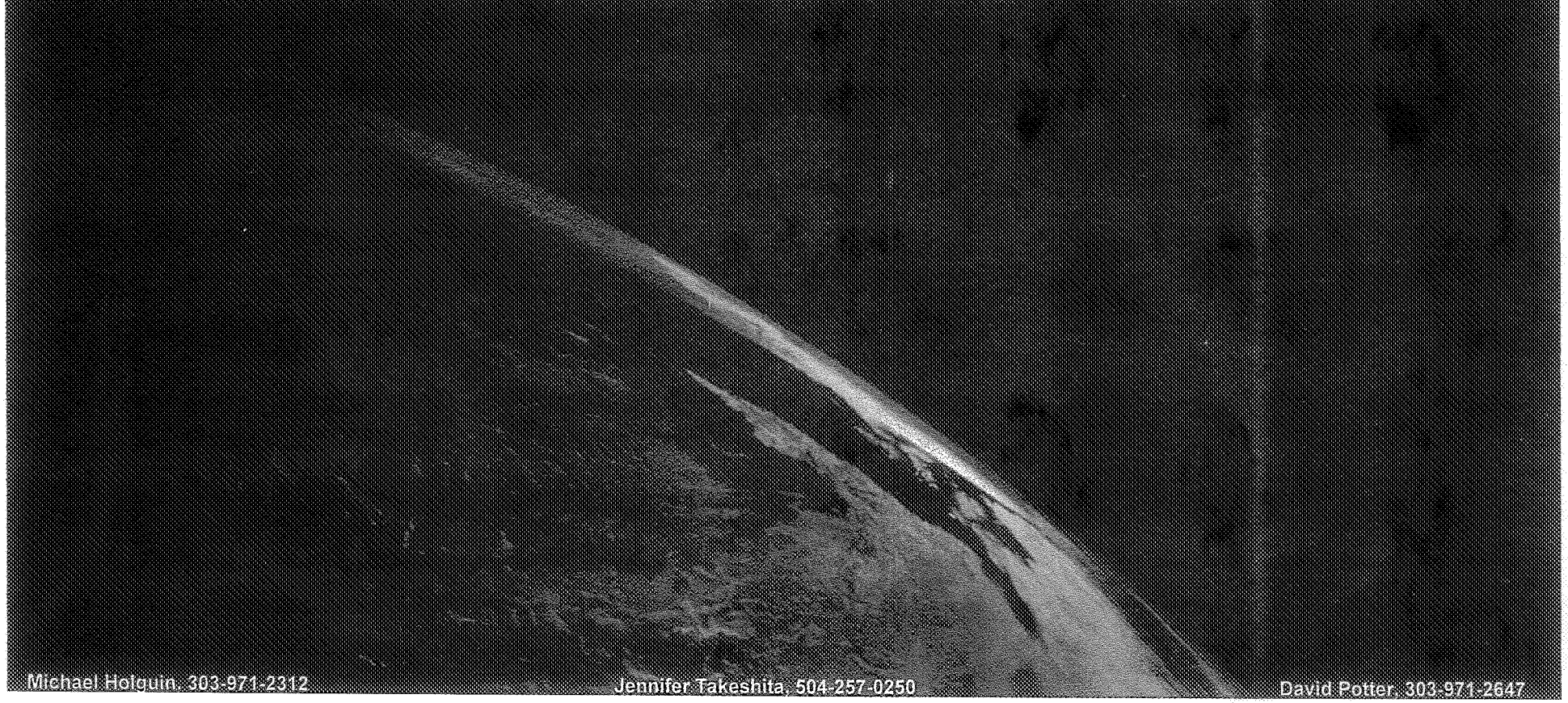
Recommendations

- Find a better way to put fasteners into epoxy die
- Use dome blanks that are one temper
  - » Anneal welds and parent metal prior to spinning



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Acknowledgements

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- NASA
  - Contract officer Louis Lollar
  - Technical counterparts Carolyn Russell
  - Program Managers: Chris Moore and Judith Watson
- Lockheed Martin
  - Bob Anderson
  - Duy Pham

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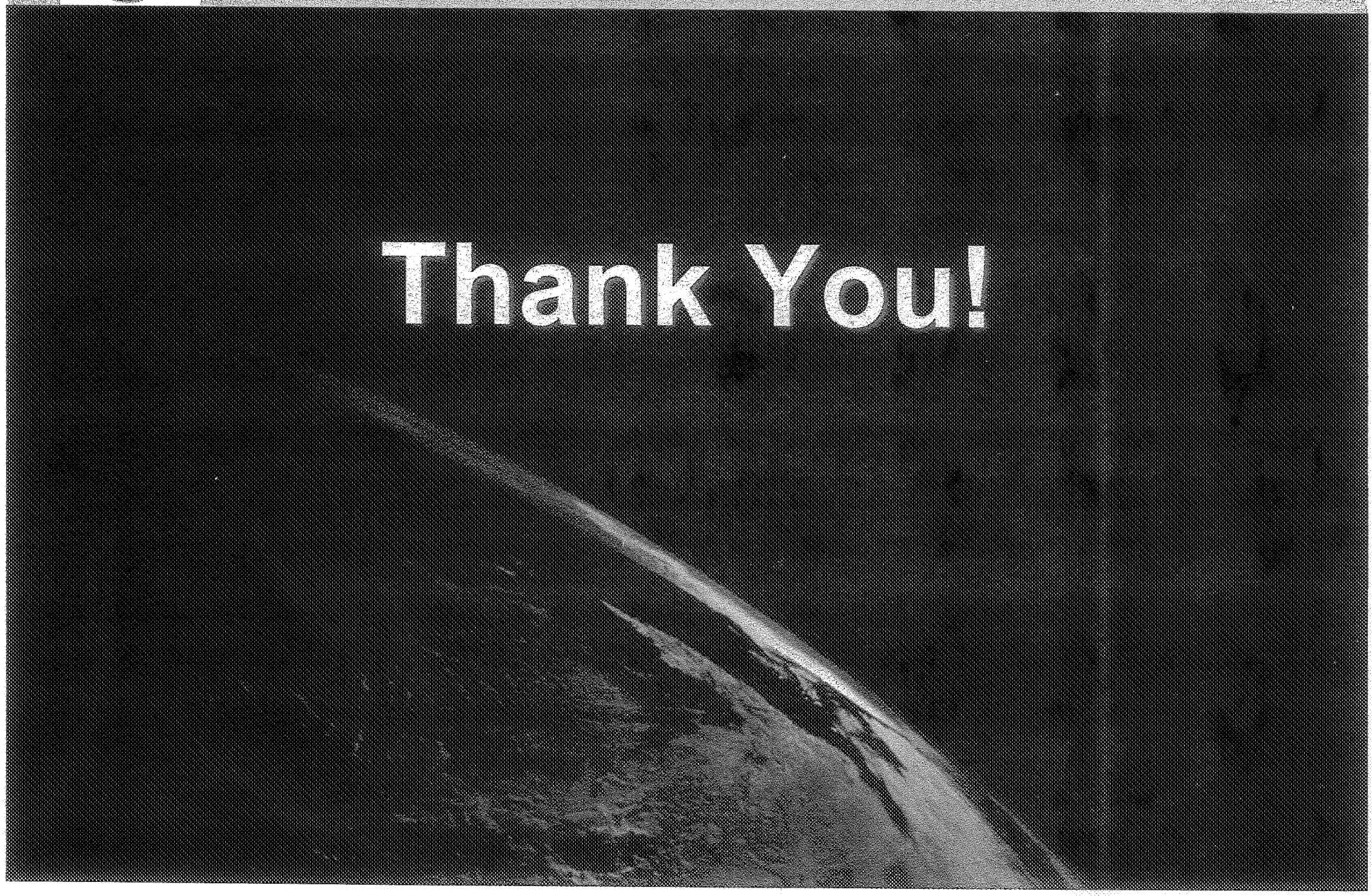
Thank You!